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From the Editors

This is the first of a sequence of three themed issues of *The Victorian Naturalist*. Long-term readers of this journal will know that diversity of subject matter is a regular feature of its contents. We feel this is a desirable feature but it is often a positive side effect of the flow of papers into the Editors' mailbox. That random flow can sometimes coalesce, however, into natural groupings, accidentally allowing the opportunity to focus on a particular aspect of the natural world. In this issue that focus is on vertebrate research. That said, there is nonetheless an inbuilt diversity in this issue - in the geographic settings of the reported research.

For the interest of readers, the two remaining issues for this year will make up the trio of subject matters as follows: October will contain papers on vegetation exclusively, and December will concentrate on invertebrates.

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Front cover: Southern Brown Tree Frog *Litoria ewingii*. Photo by Matt Kavanagh. See p. 135.
Back cover: Mountain Brushtail Possum *Trichosurus cunninghamii*. Photo by Chris Purnell. See p. 135.

Surveys of the vertebrate fauna in native grasslands of the Riverine Plain, New South Wales

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Abstract
Surveys of native grasslands for the Plains-wanderer *Pedionomus torquatus* were conducted at 12 survey sites on eight properties over five years on the Riverine Plain of southern New South Wales between November 2001 and December 2006. The main focus of these surveys was to undertake population monitoring of the threatened Plains-wanderer; however, all other vertebrate species detected, excluding macropods, also were recorded. A total of 4863 faunal observations were made, encompassing 35 native species: 24 species of bird, six reptiles, three amphibians and six mammals, of which four were introduced. Plains-wanderers were recorded at 11 of the 12 survey sites. (*The Victorian Naturalist* **126** (4) 2009, 128-134)

Keywords: native grasslands, fauna, Riverine Plain, Plains-wanderer, conservation

Introduction

The Riverine Plain of New South Wales contains a diverse range of habitats, including riverine forests, box eucalypt and cypress pine woodlands, acacia and chenopod shrublands and native grasslands (Eardley 1999). Of these, the native grasslands are among the most threatened and poorly conserved ecosystems in south-eastern Australia (McDougall and Kirkpatrick 1994; Baker-Gabb 1998; Eardley 1999). Grasslands may appear to be simple-structured communities (Lunt 1991) but their floristic diversity, faunal composition and the interactions between the two illustrate their complexity (Baker-Gabb 1998; Lunt *et al.* 1998; Hadden 2002).

Since European settlement, native grasslands have been greatly altered in extent by agriculture and livestock production (Benson 1991; Lunt 1991; McDougall and Kirkpatrick 1994). Native grasslands contain a disproportionately large number of threatened plant and fauna species such as the Plains-wanderer *Pedionomus torquatus* (Baker-Gabb 1998). A significant decline in grassland species, such as the Brown Songlark *Cincloramphus cruralis*, Australasian (Richard's) Pipit *Anthus novaeseelandiae*, Horsfield's (Singing) Bushlark *Mirafra javanica* and Banded Lapwing *Vanellus tricolor*, has been observed in recent years (Barrett *et al.* 2003).

Effective long-term conservation of these grasslands requires clear objectives, strategic planning, and active management by a range of land managers, to ensure that the status of wildlife populations and their habitats are maintained and improved (Baker-Gabb 1998; Bennett *et al.* 1998). The principal aim of the study presented in this paper was to monitor changes in the population of the endangered Plains-wanderer in native grasslands of the Riverine Plain, NSW, but the sampling technique also allowed detailed counts of other grassland fauna to be conducted. Thus, this paper also documents the vertebrate species, except macropods, recorded in these native grasslands.

Methods

Study sites

Twelve monitoring grids were established in native grasslands on the Riverine Plain of NSW between Conargo (35°18'09" S, 145°10'43" E) and Jerilderie (35°21'36" S, 145°43'37" E) in the south and between Hay (34°30'51" S, 144°50'44" E) and Carrathool (34°36'25" S, 145°25'33" E) (south of the Sturt Highway) in the north. Four grids were established on Oolambeyan National Park, one on a travelling stock route and seven on private property. Selection of sites for placement of grids was determined using historical information on Plains-wanderers contained in Maher (1997), vegetation mapping by Roberts and Roberts (2001), personal observation and landowner consent. These sites were located in grasslands with different floristic composition, physical structure and grazing management regimes.

Survey method

Although there was some variation in shape and size, a typical grid measured 50 ha in size and was 1000 m long and 500 m wide. The grids were formed by placing 1.5 m flexible poles every 200 m along parallel transects that were 50 m apart. The flexible poles were spring-loaded to prevent them being damaged by stock or used as perches by raptors. Each pole was fitted with a band of reflective tape that was detectable at night by spotlight from 200 m away. Nocturnal fauna surveys were conducted by driving a vehicle at <5 kph along the transects and spotlighting to a distance of 15-20 m, depending on the height and density of the grass. Field surveys were conducted twice yearly from the vehicle from November 2001 to December 2006, typically during June (Winter) (i.e. Round 1) and November (late Spring) (i.e. Round 2). Each grid was surveyed twice during each round. This was on consecutive nights; however, weather conditions (rain, strong winds, dust storms etc.) and/or accessibility meant some sites were not surveyed during a round.

Although the main purpose of the survey was to detect and monitor the number of Plains-wanderers at each site, the presence and abundance of other vertebrate species inhabiting the grasslands also were recorded. Only those species observed on the grid were recorded, though opportunistic (off-grid) observations also were noted. Occasional hand-capturing of individuals was required to aid identification.

Results

A total of 35 native species (three amphibians, six reptiles, 24 birds and two mammals - excluding macropod) including one threatened species, the Plains-wanderer, and four introduced species (all mammals), were recorded during eleven rounds of monitoring between November 2001 and December 2006. In total, 4865 individuals were recorded from 245 spotlighting sessions over a total of 631 hours and covering 3675 km (Table 1). Most observations (83%; 3968) were of birds, particularly Australasian Pipit (35% of all animals observed). Five species accounted for 83% of observations: Australasian Pipit, Fat-tailed Dunnart *Sminthopsis crassicaudata*, Stubble Quail *Coturnix pectoralis*, Banded Lapwing and Brown Songlark.

Amphibians

Frogs were not detected in any great numbers, with only three species encountered. Frogs were detected at six of the 12 sites, with two or three individuals of each species being recorded in total (Table 2). Small swampy areas or depressions occurred on or near to (<200m) five of the twelve grids. These were dry on the surface during most of the survey period and held water only after significant rains during two survey rounds (Spring/Summer 2004 and Winter 2005).

Reptiles

Six species of reptile were recorded from 10 of the 12 survey sites, with a total of 65 individuals observed (Table 3). Three species were recorded during spotlight events: the Curl Snake *Suta suta* was recorded at eight sites, the Eastern Hooded Scaly-foot *Pygopus schraderi* at six sites and the Tessellated Gecko *Diplodactylus tessellatus* at three sites. Three other reptiles also were recorded: the Shingleback Lizard *Trachydosaurus rugosus* and Eastern Bearded Dragon *Pogona barbata* were both observed from two sites each, roosting at the base of thick grass tussocks, while an Eastern Brown Snake *Pseudonaja textilis* was observed from one site and was in the process of entering a burrow.

One additional reptile species, the Red-naped Snake *Furina diadema*, was observed opportunistically at one site during vegetation sampling in the daytime.

Birds

A total of 24 species of bird, all of which were native, were recorded during the survey period (Table 4). Of the bird species recorded, six (Stubble Quail, Little Button-quail *Turnix velox*, Plains-wanderer, Banded Lapwing, Australasian Pipit and Brown Songlark) constituted approximately 95% of all individuals observed. The Australasian Pipit was the most abundant species encountered (42.5%), recorded from all study sites, and at one or more sites during all survey rounds. Similarly, the Stubble Quail and Banded Lapwing were recorded from all 12 study sites. The endangered Plains-wanderer was detected at eleven of the twelve study sites and was observed within sparse native grasslands during ten of the 11 survey rounds. All other species made up less than 1% each of the total birds observed.

Table 1. Survey effort across the study sites.

Site No.	Average length of grid (km)	No. survey nights	Total distance (km)	Total time (hrs:mins)	Total No. of individuals
1	7.1	20	142.4	23:05	130
2	11.6	20	232.1	43:10	230
3	16.8	20	337.0	57:39	294
4	12.1	22	267.9	48:20	317
5	18.4	21	387.1	63:06	262
6	18.3	22	402.3	69:17	464
7	16.8	22	369.6	65:05	1067
8	16.3	22	358.8	63:09	671
9	15.3	22	336.0	58:43	515
10	18.5	22	408.4	68:28	302
11	14.2	16	226.8	38:36	350
12	12.9	16	206.8	32:35	261

Table 2. Amphibian species recorded from native grasslands of the Riverine Plain.

Common Name	Scientific Name	Total count	Total sites where species recorded
Giant Banjo Frog	*Limnodynastes interioris*	2	2
Spotted Marsh Frog	*Limnodynastes tasmaniensis*	2	2
Common Spadefoot Toad	*Neobatrachus sudelli*	3	2
Unidentified frog		2	1

Table 3. Reptile species recorded from native grasslands of the Riverine Plain. # = incidental record.

Common Name	Scientific Name	Total count	Total sites where species recorded
Tessellated Gecko	*Diplodactylus tessellatus*	5	3
Eastern Hooded Scaly-foot	*Pygopus schraderi*	27	6
Eastern Bearded Dragon	*Pogona barbata*	2	2
Shingleback Lizard	*Trachydosaurus rugosus*	2	2
Red-naped Snake#	*Furina diadema*	1	1
Eastern Brown Snake	*Pseudonaja textilis*	1	1
Curl Snake	*Suta suta*	27	8

Three species of nocturnal bird of prey were recorded. The Eastern Barn Owl *Tyto javanica* was the most common, and was observed at ten of the 12 study sites. Birds were typically observed flying over the site; however, individuals were seen to land on the ground within the site on several occasions. The Southern Boobook *Ninox novaeseelandiae* and Tawny Frogmouth *Podargus strigoides* also were recorded only on one occasion each. The former was observed flying over the site, while the latter was observed perched on fallen dead timber.

Individual or small clumps of Boree *Acacia pendula* in some grids provided roost and/or nesting sites for five diurnal bird species: Black-shouldered Kite *Elanus axillaris* (roosting and nesting), Nankeen Kestrel *Falco cenchroides* (roosting and nesting), Crested Pigeon *Ocyphaps lophotes* (roosting), Willie Wagtail *Rhipidura leucophrys* (roosting) and Australian Magpie *Cracticus tibicen* (roosting). The grassland habitat also provided ground roosting sites for the Spotted Harrier *Circus assimilis*, Wedge-tailed Eagle *Aquila audax*, Nankeen Kestrel,

Table 4. Birds species recorded from native grasslands of the Riverine Plain. + = present but exact numbers not recorded; # = incidental record.

Common Name	Scientific Name	Total count	Total sites where species recorded
Emu	*Dromaius novaehollandiae*	2	2
Stubble Quail	*Coturnix pectoralis*	783	12
Pacific Black Duck	*Anas superciliosa*	4	1
Black-shouldered Kite	*Elanus axillaris*	1	1
Spotted Harrier	*Circus assimilis*	1	1
Wedge-tailed Eagle	*Aquila audax*	1	1
Black Falcon#	*Falco subniger*	+	3
Nankeen Kestrel	*Falco cenchroides*	15	3
Little Button-quail	*Turnix velox*	280	11
Red-chested Button-quail	*Turnix pyrrhothorax*	4	1
Plains-wanderer	*Pedionomus torquatus*	172	11
Inland Dotterel	*Charadrius australis*	31	3
Banded Lapwing	*Vanellus tricolor*	543	12
Australian Pratincole	*Stiltia isabella*	29	3
Crested Pigeon	*Ochyphaps lophotes*	2	1
Southern Boobook	*Ninox novaeseelandiae*	1	1
Eastern Barn Owl	*Tyto alba*	28	11
Tawny Frogmouth	*Podargus strigoides*	1	1
Southern Whiteface	*Aphelocephala leucopsis*	1	1
Orange Chat#	*Epthianura aurifrons*	+	1
Willie Wagtail	*Rhipidura leucophrys*	1	1
Australian Magpie	*Cracticus tibicen*	32	3
Horsfield's Bushlark	*Mirafra javanica*	33	6
Australasian Pipit	*Anthus novaeseelandiae*	1688	12
Rufous Songlark	*Cincloramphus mathewsi*	2	2
Brown Songlark	*Cincloramphus cruralis*	313	12

Southern Whiteface *Aphelocephala leucopsis* and Australian Magpie. The Pacific Black Duck *Anas superciliosa* was recorded once on a section of flooded farm track.

Two additional bird species were observed opportunistically while undertaking vegetation sampling during the day. These species were: Black Falcon *Falco subniger* (three sites) and Orange Chat *Epthianura aurifrons* (one site).

Mammals

Two native mammal species (excluding macropods) were identified from the 12 study sites (Table 5). The Fat-tailed Dunnart was recorded at all 12 study sites, while the Common Dunnart *Sminthopsis murina* was recorded at three sites.

Four introduced species were recorded: the Red Fox *Vulpes vulpes*, Feral Cat *Felis catus*, House Mouse *Mus musculus*, and European Rabbit *Oryctolagus cuniculus*. The Red Fox was recorded at 10 of the 12 study sites, while the Feral Cat was encountered at only one site.

Discussion

All species recorded during this study conformed to previously known distributions. The Plains-wanderer, the target species of this study, is of state and national conservation significance (Baker-Gabb 1998; Bennett *et al.* 1998). Several other grassland species recorded during this study also are considered to be in decline in the Riverina Bioregion, which includes NSW and Victoria, and include the Brown Songlark, Australasian Pipit, Horsfield's Bushlark, and Banded Lapwing (Barrett *et al.* 2003). Five species recorded during this study are listed within Victorian State Threatened Species legislation: two critically endangered (Hooded Scaly-foot and Giant Banjo Frog *Limnodynastes interioris*); one endangered (Plains-wanderer); and two vulnerable (Red-chested Button-quail *Turnix pyrrhothorax* and Curl Snake).

The survey technique limited the detection of most reptile and amphibian species; however, the survey methods adopted were appropriate for detecting two species, the Hooded Scaly-

Table 5. Mammal species, excluding macropods, recorded from native grasslands of the Riverine Plain. * = introduced species; + = present but exact numbers not recorded.

Common Name	Scientific Name	Total count	Total sites where species recorded
Common Dunnart	*Sminthopsis murina*	8	3
Fat-tailed Dunnart	*Sminthopsis crassicaudata*	708	12
House Mouse*	*Mus musculus*	72	10
Red Fox*	*Vulpes vulpes*	34	10
Feral Cat*	*Felius catus*	1	1
European Rabbit*	*Oryctolagus cuniculus*	+	1

foot and the Curl Snake. These species are terrestrial and nocturnal and utilise a range of habitats including grasslands (Cogger 1992; Swan *et al.* 2004). Both of these species are often associated with fallen timber, and surface rocks, but also ant and termite nests and deep earth cracks (Swan *et al.* 2004). All of these refuges, except surface rocks, were present at those sites where these species were recorded. The Tessellated Gecko, though considered cryptic (Brown and Bennett 1995), was recorded during this study. This species is widely distributed throughout dry regions of central and eastern Australia (Cogger 1992). The study area represents the eastern limit of its range (Swan *et al.* 2004; Atlas of NSW Wildlife 2007). The Giant Banjo Frog and the Common Spadefoot Toad *Neobatrachus sudelli* are burrowing fossorial species that spend much of their life concealed underground, emerging only after substantial rains (Hero *et al.* 1991; Bennett *et al.* 1998). It was only after such events that all three species of frog were encountered during this study. It is very likely that many more reptile and amphibian species would have been recorded if a greater range of survey methods had been applied.

Birds were the most diverse group of vertebrate fauna recorded in native grasslands. The results of this study concur with those of others examining bird communities in Riverina grasslands in NSW (Baker-Gabb *et al.* 1990; Maher 1997) and in northern Victoria (Maher and Baker-Gabb 1993). While the commonly recorded Australasian Pipit is sedentary or locally nomadic, both the Stubble Quail and Banded Lapwing are considered nomadic, with movements influenced by rainfall (Marchant and Higgins 1993). In a descriptive account of grassland birds from two Riverina properties, Baker-Gabb *et al.* (1990: 164) stated that: 'Plains-wanderers and Richard's Pipit were always present. Banded Lapwings were absent for up to three months, while the Stubble Quail, Brown Songlark and Singing [Horsfield's] Bushlark were absent for up to five months, and Little Button-quail were away for much longer periods'. Baker-Gabb *et al.* (1990) encountered 401 Horsfield's Bushlarks over a total driven distance of 2121 km (665 hrs), while this study encountered only 33 individuals over a total driven distance of 3675 km (631 hrs). Barrett *et al.* (2003) noted a 20% decline in the reporting rate of the Horsfield's Bushlark in the New Atlas of Australian Birds (1998-2002) compared to the Atlas of Australian Birds (1977-81), with the Riverina Bioregion being one of the areas in which this decline was evident.

The Inland Dotterel and Australian Pratincole are spring/summer visitors to native grasslands on the Riverine Plain. Their movements often correlated with annual summer rainfall, escape from dry periods elsewhere, or migration (Higgins and Davies 1996). During the survey period, these two species were irregular visitors and were present only when habitat conditions were suitable. The Red-chested Button-quail was recorded on only one occasion—an adult with three chicks—during spring 2003. Native grasslands appear to be the preferred habitat of the species (Bennett *et al.* 1998); however, it has been recorded from other vegetation types such as grassy woodlands (Marchant and Higgins 1993). This species is regarded as being generally uncommon across Australia, but apparently secure (Marchant and Higgins 1993). Maher (1997) recorded the Red-chested Button-quail only twice in native grasslands on the Riverine Plain during surveys between 1995 and 1997.

The Fat-tailed Dunnart was the most common native mammal recorded during the study and occurs mostly in open vegetation on a

variety of soil and vegetation types, including open woodlands, low chenopod shrublands, tussock grasslands and gibber plains (Dickman and Read 1992; Morton 1995). It is regarded as the most widespread and abundant dasyurid in western NSW (Dickman and Read 1992). Recent faunal studies in native grasslands of the Northern 'Riverine' Plains of Victoria (Hadden 2002; Michael *et al.* 2003) also found this species to be common in sites that were lightly grazed and contained open vegetation cover. The Common Dunnart was irregularly recorded during this study and is considered to be sparsely distributed across south-eastern Australia, mostly inhabiting woodland, forest and scrub (Dickman and Read 1992; Fox 1995). In a study of the mammalian fauna of remnant native grasslands in Victoria, Hadden (2002) recorded the Common Dunnart only once, from native grasslands on the Western Basalt Plains. The presence of Common Dunnart during this survey supports Hadden's (2002) suggestion that the species may occupy grassland habitats, particularly in close proximity to woodland vegetation.

Despite the limited sampling techniques applied during this study, the results highlight the importance of the native grasslands on the NSW Riverina Plains for a range of fauna. While recent acquisitions by the NSW State Government have increased significantly the amount of native grassland contained within the reserve system in the Riverina Bioregion, most native grasslands occur on privately owned land. Bennett *et al.* (1998: 74) state, 'the future of the wildlife of the [Victorian] Riverina is not solely the responsibility of government or any single agency: it depends ultimately on the concern and actions of the whole community.' The retention and maintenance of native grassland habitat across all tenures is critical for the conservation of species such as the Plains-wanderer, as well as other grassland flora and fauna. There are new opportunities for incentive-based management agreements on private land for biodiversity conservation.

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Yellow-faced Honeyeater *Lichenostomus chrysops.* Photo by Heath Maconochie. See p. 135.

Survival of vertebrate fauna in remnant vegetation patches and colonisation of revegetation areas in the La Trobe Valley, Victoria

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Abstract
Expansion of open-cut coal mines in the La Trobe Valley, Victoria, will lead to the loss of native vegetation and vertebrate habitat. Corporations operating these mines have entered into agreements to manage offset areas for conservation values. Surveys of vertebrate fauna in seven offset areas and revegetation sites were carried out between February 2005 and May 2008. One hundred and twenty-eight species were recorded, comprising 21 mammals, 11 reptiles, eight amphibians and 88 birds. Several threatened species were recorded including Swamp Skink *Egernia coventryi*, Powerful Owl *Ninox strenua*, Australasian Shoveler *Anas rhynchotis*, Blue-billed Duck *Oxyura australis*, Eastern Great Egret *Ardea modesta*, Royal Spoonbill *Platalea regia*, and White-bellied Sea-Eagle *Haliaeetus leucogaster*. Several species had colonised revegetation areas and others were detected in degraded sites and isolated remnant patches. The ability of these species to survive in fragmented and disturbed habitats is discussed. The results of these surveys have implications for land managers planning conservation works or habitat enhancement programs especially in degraded sites. (*The Victorian Naturalist* **126**, (4) 2009, 135-150)

Keywords: fragmentation, revegetation, colonisation, threatened species, degraded habitat

Introduction

Several open-cut coal mines have existed in the La Trobe Valley, Victoria, for many decades, and in recent years two corporations operating these mines have sought to expand coal field development. Such further expansion will, however, lead to the loss of native vegetation and wildlife habitat. As a consequence, these corporations have entered into conservation agreements with the Victorian Government to protect significant vegetation in and around coal field development areas (DNRE 2002). A principal aim of these agreements is to ensure the conservation, enhancement and re-establishment of Ecological Vegetation Classes (EVCs) and significant taxa impacted by coal field development.

International Power Pty Ltd, which operates the Morwell open-cut coal mine, has entered into an agreement to replace wetlands that will be lost as a result of coal-field expansion. These replacement wetlands are known as the Morwell River Wetlands. TRU Energy Pty Ltd, which operates the Yallourn open-cut coal mine, has also entered into an agreement to protect important native vegetation and to manage offset areas for conservation values. These offset areas form part of the Yallourn Mine Conservation Management Plan (YMCMP). Indigenous Design Land Management Pty Ltd (IDLM), an environmental consultancy, conducts vegetation surveys and vegetation assessments and carries out conservation works on behalf of both corporations. These works include weed removal and control, revegetation and habitat enhancement programs. The conservation agreements include a monitoring program that requires periodic reports to the Department of Sustainability and Environment (DSE) on the progress of conservation works. In particular, the reports must provide information about which species of vertebrates are inhabiting offset areas and those species that may be colonising revegetation sites. Surveys to determine the presence and relative abundance of mammals, reptiles, amphibians and birds in seven offset areas and revegetation sites were therefore commissioned by International Power Pty Ltd and TRU Energy Pty Ltd. The data collected during these surveys were to be used in the preparation of these reports. The surveys were carried out between February 2005 and May 2008.

Survey sites

The seven areas surveyed contain seven EVCs (DSE 2004). They include the Morwell River Wetlands and six offset areas within the YMCMP. The survey sites are centred around the

townships of Morwell and Yallourn North, on the Gippsland Plain, approximately 135 km east-south-east of Melbourne. The original natural environment is significantly altered, with several townships, coal mines, power stations and associated infrastructure; quarries, softwood and hardwood plantations; a network of roads and highways; railway lines; and intensive agriculture. Each site has suffered varying degrees of disturbance over many years, including grazing, firewood collection and some dumping of rubbish. All contain numerous species of common, introduced weed species, especially on the periphery of the sites. However, most sites contain excellent examples of the original vegetation that covered the district prior to European settlement. Some sites were subject to grazing leases; however, these have now been cancelled and all areas are fenced to exclude stock from neighbouring properties. The general public is also excluded from all offset areas and revegetation sites. Each site was inspected during a one day preliminary assessment before intensive fauna survey work was carried out at a later date, as shown below. All sites are covered by Natmap 1:100 000, Sheet No. 8121 (Moe) and the AMG is given for the central point of each site.

Site 1. Morwell River Wetlands, about 2 km south-west of Morwell, approximately 40 ha, Artificial Wetland with degraded Swamp Scrub and degraded Riparian Forest, AMG: 444680, altitude 40 m

Construction of these wetlands began in 1999, when the flow of the Morwell River was altered. The area flooded for the first time in 2001. Extensive conservation works have been carried out including formation of islands and planting of indigenous vegetation, especially Swamp Paperbark *Melaleuca ericifolia* and the rare Strzelecki Gum *Eucalyptus strzeleckii*. A wide range of wetland plants have been established, and waterfowl nest-boxes and woody debris have been provided. Prior to the establishment of the wetlands two small areas of degraded Swamp Scrub, with Swamp Paperbark, Common Reed *Phragmites australis*, with some Thatch Saw-sedge *Gahnia radula*, Common Tussock-grass *Poa labillardierei* and numerous weed species (covering about two ha) survived at the southern edge of the site. Another small area of degraded Riparian Forest (covering about two ha) survived along the eastern bank of the Morwell River at the northern edge of the site. Several remnant old-growth Strzelecki Gum with an understorey of Silver Wattle *Acacia dealbata* survived in this riparian zone, along with a small adjoining area of Manna Gum *Eucalyptus viminalis* and a thick ground cover of Common Tussock-grass. Numerous fallen logs were also present in this area. The survey of the Morwell River Wetlands was conducted over five days and four nights from 22 to 26 February 2005.

Site 2. Riparian Forest, Swampy Riparian Complex and Plains Grassy Forest, about 4.5 km north of Morwell, approximately 31 ha, AMG: 470721, altitude 60-90 m

Most of this site is Plains Grassy Forest. The northern section, covering about 16 ha, is in excellent condition, while the southern section (about 11 ha) is degraded. The Plains Grassy Forest occurs on a slight slope above a narrow gully that supports Swampy Riparian Complex (2 ha) and Riparian Forest (2 ha). The overstorey in the Plains Grassy Forest consists of Messmate *Eucalyptus obliqua* and Narrow-leaf Peppermint *E. radiata*, with occasional Apple-topped Box *E. angophoroides*. There is a sparse shrub layer consisting of Prickly Moses *Acacia verticillata*, Snowy Daisy Bush *Olearia lirata*, Dogwood *Cassinia aculeata* and Burgan *Kunzea ericiodes*. Ground cover includes Austral Bracken *Pteridium esculentum*, Grey Parrot Pea *Dillwynia cinerascens*, Spiny Mat-rush *Lomandra longifolia*, Wattle Mat-rush *L. filiformis* and numerous native grasses including Weeping Grass *Microlaena stipoides*. Numerous fallen logs and old-growth trees with various sized hollows are a feature of the northern section of this site. The overstorey of the Swampy Riparian Complex and Riparian Forest consists of Strzelecki Gum. Understorey includes Scented Paperbark *Melaleuca squarrosa*, with several species on the drier periphery including Blackwood *Acacia melanoxylon*, Prickly Teatree *Leptospermum continentale*, Black Wattle *A. mearnsii*, Prickly Currant-bush *Coprosma quadrifida*, Swamp Paperbark and Prickly Moses. Ground cover consists of Fishbone Water Fern *Blechnum nudum*, Tall Sedge *Carex appressa*, Square Twig-rush *Baumea tetragona*, the introduced Bulrush *Typha latifolia* and Thatch Saw-sedge. Numerous fallen logs exist in the gully. This site was surveyed between 26 and 29 March 2007.

Site 3. Artificial Wetlands, degraded Swamp Scrub, about 2 km north-west of Morwell, approximately 22 ha, AMG: 445694, altitude 40 m

This area contains three large artificial wetlands, known as the Yallourn Wetlands, which occur on three tiers above the Morwell River. The first is a large, relatively deep, old farm dam that was built prior to 1966. A large part of this dam is fringed by a thick bed of Common Reed. The other two wetlands were constructed between 2000 and 2004. Major revegetation and earthworks have occurred, with the construction of islands and associated habitat enhancement works including provision of waterfowl nestboxes and woody debris. Prior to the construction of the wetlands, a small area of degraded Swamp Scrub, with Swamp Paperbark, Common Reed and some sedge species survived next to the old farm dam. A small drainage area with Tufted Sedge *Carex gaudichaudiana* also exists above the oldest dam. The survey of this site took place between 12 and 15 November 2007.

Site 4. Riparian Forest and degraded Swamp Scrub, about 3.25 km north-west of Morwell, approximately 27 ha, AMG: 448699, altitude 40-50 m

This site adjoins the northern boundary of site 3 and follows the east bank of the Morwell River north for about 1.25 km. The southern section contains a large, low-lying area of degraded Swamp Scrub with Swamp Paperbark, Common Reed and the introduced Toowoomba Canary-grass *Phalaris aquatica*. Many large, dead eucalypt stags are a feature of this swampy area. The site becomes steeper and narrower towards the north, where high quality Riparian Forest has an overstorey of Strzelecki Gum and Manna Gum. Dominant species in an open understorey include Mutton-wood *Rapanea howittiana*, Tree Violet *Hymenanthera dentata*, Tree Everlasting *Ozothamnus ferrugineus*, Burgan, Silver Wattle and some Swamp Paperbark. Ground cover includes Tussock Grass *Poa sieberiana*, Spiny Mat-rush, Thatch Saw-sedge, Weeping Grass and a large area with a thick cover of Variable Sword-sedge *Lepidosperma laterale var. majus*. This site also contains many fallen logs. The survey of this site took place between 19 and 22 March 2007.

Site 5. Degraded Reed Swamp and degraded Riparian Forest, about 2 km west of Morwell, approximately 7 ha, AMG: 441686, altitude 40 m

This low-lying site is on the west bank of the Morwell River adjacent to the northern section of the Morwell River Wetlands. The riparian zone is similar to that on the eastern bank of the river with several old growth Strzelecki Gum, and an understorey of Silver Wattle. A major revegetation program using Strzelecki Gum and Silver Wattle has been completed on the flood plain. Next to the revegetation area a large expanse of Reed Swamp exists, containing Cumbungi *Typha domingensis*, Common Reed and Toowomba Canary-grass. The western edge of the site, which was previously grazed, is an elevated area with numerous weed species including Sweet Vernal Grass *Anthoxanthum odoratum*, and Yorkshire Fog *Holcus lanatus*. This section has undergone a major revegetation program with numerous indigenous shrub and sedge species. This site was surveyed between 13 November 2007 and 16 November 2007.

Site 6. Lowland Forest, Damp Forest, and Swampy Riparian Complex, about 2 km south of Haunted Hills, approximately 37 ha, AMG: 395695, altitude 100-200 m

This site is a relatively narrow, isolated gully, stretching for about 2.5 km, which contains Damp Forest with Lowland Forest on the higher sections. A large, deep storage dam which supplies water to the Yallourn open-cut mine exists at the northern end of this site. The Damp Forest section supports an overstorey of Messmate and Narrow-leaf Peppermint. Dominant species in a dense understorey include Musk Daisy-bush *Olearia argophylla*, Hazel Pomaderris *Pomaderris aspera*, Silver Wattle, Blackwood and Prickly Currant-bush, with numerous Rough Treefern *Cyathea australis*. Ground cover includes Gristle Fern *Blechnum cartilagineum* and Thatch Saw-sedge. Due to the dense understorey, ground cover is very sparse in several parts of the gully. Two small, overgrown dams exist in the gully, one with some Common Reed. The Lowland Forest supports an overstorey of Messmate, Narrow-leaf Peppermint and Yertchuk *Eucalyptus consideniana* with a shrub layer including Variable Sallow Wattle *Acacia mucronata*, Shiny Cassinia *Cassinia longifolia*,

Burgan, Prickly Tea-tree, Hazel Pomaderris and Snowy Daisy-bush. Two small areas of Hairpin Banksia *Banksia spinulosa* also exist. Ground cover includes Small Grass Tree *Xanthorrea minor,* Common Heath *Epacris impressa*, Forest Wiregrass *Tetrarrhena juncea*, Wattle Mat-rush and Austral Bracken. The Swampy Riparian Complex is a small section of this site and is located at the northern end below the storage dam. It has an overstorey of Swamp Gum *Eucalyptus ovata* with an understorey of Scented Paperbark, Prickly Tea-tree and Rough Treefern. A thick ground cover includes Red-fruited Saw-sedge *Gahnia sieberiana*, Hop Goodenia *Goodenia ovata*, Variable Sword-sedge and Tall Sedge. Site 6 is the only site within the YMCMP that contains very large numbers of tall, old-growth eucalypts, with many hollows of all sizes, and many large, fallen hollow logs. The survey of this site took place between 28 April and 1 May 2008.

Site 7. Grassy Dry Forest and Damp Forest, about 1km south-west of Yallourn North, approximately 23 ha, AMG: 430753, altitude 60-120 m

This block contains three gullies which support Damp Forest with an overstorey of Messmate, Narrow-leaf Peppermint and some Manna Gum. The understorey includes Blanket Leaf *Bedfordia arborescens*, Silver Wattle, Blackwood, Musk Daisy Bush, Hazel Pomaderris and Prickly Currant Bush with some Rough Tree fern. The ground cover includes a thick cover of Fishbone Water Fern, Thatch Saw-sedge and Austral Bracken. The Plains Grassy Forest above the gullies has an overstorey of Messmate and Narrow-leaf Peppermint, with a shrub layer of Dusty Miller *Spyridium parvifolium*, Burgan, Snowy Daisy Bush, Prickly Tea Tree, Shiny Cassinia and Prickly Moses. An open ground cover includes Slender Tussock Grass *Poa tenera*, Weeping Grass, Wattle Mat-rush and some Thatch Saw-sedge. In the past, large scale firewood removal has occurred at this site, resulting in the survival of few good habitat trees and a scarcity of fallen logs. A wildfire in November 2006 burnt through approximately 50% of this site. The survey of site 7 took place between 12 and 15 May 2008.

Methods

A number of survey methods were used to determine the presence and relative abundance of vertebrates in each of the sites. These included Elliott trapping, Type A (Elliott Scientific Equipment, Upwey, Victoria), cage trapping (standard bandicoot traps, Wiretainers Pty Ltd, Preston, Victoria and RE Walters 1899 Pty Ltd, Sunshine, Victoria), funnel trapping (Ecosystematica Environmental Consultants, WA), harp trapping (Ecological Consulting Services, Newport, Victoria and Faunatech, Bairnsdale, Victoria), pitfall trapping, stagwatching, spotlighting on foot, active herp searching (rock, log and debris turning and scanning possible reptile basking sites with binoculars), listening (male frogs and nocturnal birds and mammals), bird observation and general observation (chance sightings and observations of incidental evidence, such as scats and diggings). Pitfall trapping was carried out in February 2005, only at the Morwell River Wetlands. Two lines of five 20 l plastic buckets, spaced at five metre intervals, with a 30 cm high, aluminium flywire drift fence stretching over 30 m, were established. During subsequent surveys funnel traps were used as the preferred method for surveying reptiles. This was due to the ease of establishing funnel trap lines compared to pitfall lines and their ability to capture large elapid snakes, which can normally escape from pitfall buckets.

The structure of Elliott and cage trap lines varied depending on the site. Some lines were set around the edge of wetlands or along watercourses and varied in length, whilst others were set in grids. Generally traps were spaced 10 m apart in thick vegetation and 25 m apart in open habitats. Where grids were established, transects were 25 m apart. Baits consisted of quick oats, smooth peanut butter and honey, with sardines added to the mixture for cage traps. Funnel traps were set in pairs along 30 cm high, aluminium flywire drift fences, with one funnel trap on each side of the drift fence, every five m. The length of the drift fence varied depending on the site, covering between 30 and 50 m.

Active herp searching and bird observation took place at each site. The bulk of these methods occurred concurrently each morning following the checking of traps, and usually lasted for 60 minutes. Scanning of possible reptile basking sites with binoculars took place during late morning and early afternoon when conditions were conducive. At wetland sites bird observation took place each evening for approxi-

Table 1. Survey methods and effort for each site.

	Survey Sites						
Survey method	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Elliott trap-nights	80	192	90	120	30	150	150
Cage trap-nights	104	78	90	72	30	150	150
Funnel trap-nights		90	36	60	34		
Harp trap-nights	6	6		4		6	6
Pitfall trap-nights	25						
Stagwatching(no.of stags)		2			2	4	
Spotlight hours	2	4.5		5	2	10	7.5

mately 30 minutes. Stagwatching took place at sites where suitable habitat trees existed. Spotlighting on foot was carried out at six sites.

Overall, 1759 trap-nights were completed. These consisted of 812 Elliott trap-nights, 674 cage trap-nights, 25 pit-nights, 220 funnel trap-nights and 28 harp trap-nights. Eight stags were watched and 31 spotlight hours were completed (Table 1).

Results

One hundred and twenty-eight vertebrate species were recorded. These included 21 mammals (Table 2) of which 11 were eutherian, nine marsupial and one monotreme. Eighteen of the mammal species were native and three were introduced.

The Agile Antechinus *Antechinus agilis* (Fig. 1) was recorded at three sites in Damp Forest, Plains Grassy Forest, Lowland Forest and Swampy Riparian Complex. The Dusky Antechinus *A. swainsonii* was found at one site only in an area of Damp Forest with thick ground cover. The Common Brushtail Possum *Trichosurus vulpecula* was recorded in several areas of Riparian Forest, whilst the Mountain Brushtail Possum *T. cunninghamii* (see back cover) was recorded in Damp Forest and Lowland Forest at one site only. The Sugar Glider *Petaurus breviceps* was found in degraded Riparian Forest along the Morwell River, where several old-growth habitat trees with an understorey of Silver Wattle occurred.

Large numbers of Common Ringtail Possum *Pseudocheirus peregrinus* were seen whilst spotlighting in Lowland Forest, Plains Grassy Forest, Damp Forest, and Riparian Forest. Smaller numbers were also detected in degraded Swamp Scrub. Six species of insectivorous bats were recorded, including Little Forest Bat *Vespadelus vulturnus* (Riparian Forest and Plains Grassy Forest), Large Forest Bat *V. darlingtoni* (Riparian Forest), Chocolate Wattled Bat *Chalinolobus morio* (Damp Forest and Riparian Forest), Gould's Wattled Bat *C. gouldii* (Riparian Forest and Plains Grassy Forest), Lesser Long-eared Bat *Nyctophilus geoffreyi* (Plains Grassy Forest, Riparian Forest and revegetation area beside artificial wetland) and White-striped Freetail Bat *Tadarida australis* (Lowland Forest).

The Bush Rat *Rattus fuscipes* was found in Riparian Forest, Damp Forest, Swampy Riparian Complex and degraded Swamp Scrub at five sites where moderate to thick ground cover occurred, usually with the presence of fallen logs. The species was also recorded in one revegetation area. The Swamp Rat *R. lutreolus* was recorded in degraded Swamp Scrub, Swampy Riparian Complex and areas of introduced grasses and weeds in five sites. Swamp Rats were also detected around artificial wetlands and in revegetation areas. Evidence of the Short-beaked Echidna *Tachyglossus aculatus* was found in Plains Grassy Forest and Lowland Forest at several sites, and one was captured in a cage trap set beside an artificial wetland. Common and scientific names and taxonomy for mammals follow Menkhorst (1995), except for Agile Antechinus *Antechinus agilis* and Mountain Brushtail Possum *Trichosurus cunninghamii,* which follow Van Dyck and Strahan (2008).

Eleven species of reptiles were recorded (Table 3). These included one freshwater turtle, eight skinks and two elapid snakes. The Swamp Skink *Egernia coventryi* (Fig. 2) and Glossy Grass Skink *Pseudemoia rawlinsonii* were both recorded in weedy, disturbed areas near degraded Reed Swamp. The Swamp Skink is classified as vulnerable in Victoria, and the Glossy Grass Skink is recognised as near threatened (DSE 2007). Several other species were detected in disturbed and degraded sites, including

Table 2. List of mammals and numbers recorded for each survey site. * = introduced species; i = indirect evidence (scats, diggings etc.)

		Survey sites						
Species		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Short-beaked Echidna	*Tachyglossus aculeatus*		i	1			i	
Agile Antechinus	*Antechinus agilis*		23				56	8
Dusky Antechinus	*Antechinus swainsonii*							10
Common Wombat	*Vombatus ursinus*		i	i	i		2	
Sugar Glider	*Petaurus breviceps*	5			1	5		
Common Ringtail Possum	*Pseudocheirus peregrinus*	2	22		1		57	
Mountain Brushtail Possum	*Trichosurus cunninghamii*						5	
Common Brushtail Possum	*Trichosurus vulpecula*	7			6			1
Eastern Grey Kangaroo	*Macropus giganteus*		5				3	
Black Wallaby	*Wallabia bicolor*		3		4		3	1
White-striped Freetailed Bat	*Tadarida australis*					3	1	
Lesser Long-eared Bat	*Nyctophilus geoffroyi*	4	2		5			
Gould's Wattled Bat	*Chalinolobus gouldii*		1		1			
Chocolate Wattled Bat	*Chalinolobus morio*				1		1	
Large Forest Bat	*Vespadelus darlingtoni*				7			
Little Forest Bat	*Vespadelus vulturnus*		5		6			
Swamp Rat	*Rattus lutreolus*	6		1	4	i	i	
Bush Rat	*Rattus fuscipes*	20	5		38		20	8
House Mouse	*Mus musculus* *	11		1			1	12
Red Fox	*Vulpes vulpes* *	i		i			i	i
European Rabbit	*Oryctolagus cuniculus* *	2	1	11		1	1	1

Fig. 1. Agile Antechinus *Antechinus agilis*. Photo by Maryrose Morgan.

Metallic Skink *Niveoscincus metallicus*, Blotched Blue-tongued Lizard *Tiliqua nigrolutea*, Delicate Skink *Lampropholis delicata*, Weasel Skink *Saproscincus mustelinus* and Lowland Copperhead *Austrelaps superbus*. Lowland Copperheads were also seen basking at several sites. Tiger Snake *Notechis sculatus* was captured in funnel traps in Plains Grassy Forest, Riparian Forest and degraded Swamp Scrub. Staff from IDLM report seeing Tiger Snake and Lowland Copperhead in several revegetation sites throughout the district.

The Common Long-necked Turtle *Chelodina longicollis* was found near the oldest and deepest wetland at site 3. The secretive McCoys Skink *Nannoscincus maccoyi* was found under an old car door in Grassy Dry Forest. Common and scientific names and taxonomy for reptiles follow the Atlas of Victorian Wildlife, DSE.

Eight species of amphibians were recorded, including three tree frogs and five southern frogs (Table 4). Several species had colonised artificial wetlands at sites 1 and 3. These included Southern Brown Tree Frog *Litoria ewingii* (see front cover), Verreaux's Tree Frog *Litoria verreauxi*, Common Froglet *Crinia signifera*,

Table 3 List of reptiles and numbers recorded for each site. T = threatened species.

		Survey sites						
Species		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Common Long-necked Turtle	*Chelodina longicollis*			3				
Swamp Skink	*Egernia coventryi*, **T**					1		
Delicate Skink	*Lampropholis delicata*		3		14	2		
Garden Skink	*Lampropholis guichenoti*	1	3				2	
McCoys Skink	*Nannoscincus maccoyi*							2
Metallic Skink	*Niveoscincus metallicus*	7		38	2	19		
Glossy Grass Skink	*Pseudemoia rawlinsoni*					1		
Weasel Skink	*Saproscincus mustelinus*	2	4	1	8			1
Blotched Blue-tongued Lizard	*Tiliqua nigrolutea*					2		
Tiger Snake	*Notechis scutatus*		2		2			
Lowland Copperhead	*Austrelaps superbus*	1	3	1		2		

Table 4. List of amphibians and numbers recorded for each site.

		Survey Sites						
Species		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Southern Brown Tree Frog	*Litoria ewingii*	3	4	7	3	2	2	2
Verreaux's Tree Frog	*Litoria verreauxi*		1	1	1		1	
Perons Tree Frog	*Litoria peronii*					2		
Victorian Smooth Froglet	*Geocrinia victoriana*				6		1	2
Spotted Marsh Frog	*Limnodynastes tasmaniensis*	28						
Striped Marsh Frog	*Limnodynastes peroni*	79			5	1	1	
Common Froglet	*Crinia signifera*	2	4	10	4	10	4	3
Southern Bullfrog	*Limnodynastes dumerili*		8	2	2			

Southern Bullfrog *Limnodynastes dumerili*, Striped Marsh Frog *Limnodynastes peronii*, and Spotted Marsh Frog *Limnodynastes tasmaniensis*. One Verreaux's Tree Frog was also found under a section of log that had been placed around an artificial wetland. Southern Brown Tree Frog and Verreaux's Tree Frog were also heard in Riparian Forest and Damp Forest. Victorian Smooth Froglet *Geocrinia victoriana* was heard in degraded Swamp Scrub and Damp Forest. Perons Tree Frog *Litoria peronii* was heard in degraded Reed Swamp near the Morwell River. Striped Marsh Frog was heard in a small dam within Damp Forest. Common and scientific names and taxonomy for amphibians follow the Atlas of Victorian Wildlife, DSE.

Eighty-eight species of birds were recorded (Table 5). Eighty-three species were native and five were introduced. Two species, Pacific Black Duck *Anas superciliosa* (adult with ducklings) and White-bellied Sea-Eagle *Haliaeetus leucogaster* (active nest) were recorded as breeding. Numerous species of waterfowl and waterbirds were recorded in recently constructed artificial wetlands. These included several species classified as vulnerable in Victoria (DSE 2007). These comprised Australasian Shoveler *Anas rhynchotis*, Eastern Great Egret *Ardea modesta* and Royal Spoonbill *Platalea regia*. Latham's Snipe *Gallinago hardwickii*, which is recognised as near threatened in Victoria (DSE 2007), was also recorded in artificial wetlands. The Blue-billed Duck *Oxyura australis*, a species that prefers deep wetlands with a dense cover of fringing vegetation (Frith 1967), was recorded in the deepest and oldest wetland at site 3, which is fringed on one side by a thick reed bed. The species is classified as endangered in Victoria (DSE 2007). The White-bellied Sea-Eagle and Swamp Harrier *Circus approximans* were seen over artificial wetlands. The White-bellied Sea-Eagle is classified as vulnerable in Victoria (DSE 2007). A range of species was recorded in revegetation areas, including White-eared Honeyeater *Li-*

Table 5. List of birds and numbers recorded for each survey site. E = estimated number; * = introduced species; **T** = threatened species.

		Survey sites						
Species		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Black Swan	*Cygnus atratus*	12		5				
Australian Shelduck	*Tardorna tadornoides*			4				
Australian Wood Duck	*Chenonetta jubata*					2		
Australasian Shoveler	*Anas rhynchotis*, **T**			2				
Grey Teal	*Anas gracilis*			6				
Chestnut Teal	*Anas castanea*	2		4				
Pacific Black Duck	*Anas superciliosa*	44		13				
Blue-billed Duck	*Oxyura australis*, **T**			2				
Spotted Dove	*Streptopelia chinensis* *	2						
Common Bronzewing	*Phaps chalcoptera*				2			
Australasian Darter	*Anhinga novaehollandiae*			1				
Little Pied Cormorant	*Microcarbo melanoleucos*	3		1				
Little Black Cormorant	*Phalacrocorax sulcirostris*			14				
Australian Pelican	*Pelecanus conspicillatus*	10		3				
White-necked Heron	*Ardea pacifica*			1				
Eastern Great Egret	*Ardea modesta*, **T**	1		2				
White-faced Heron	*Egretta novaehollandiae*	3		2				
Australian White Ibis	*Threskiornis spinicollis*	10		4				
Royal Spoonbill	*Platalea regia*, **T**			1				
Black-shouldered Kite	*Elanus axillaris*			1				
White-bellied Sea-Eagle	*Haliaeetus leucogaster*, **T**			2				
Whistling Kite	*Haliastur sphenurus*				2			
Swamp Harrier	*Circus approximans*	2		3				
Wedge-tailed Eagle	*Aquila audax*					1		
Brown Falcon	*Falco berigora*	1			1			
Purple Swamphen	*Porphyrio porphyrio*	22		3				
Dusky Moorhen	*Gallinula tenebrosa*	1		4				
Eurasian Coot	*Fulica atra*	1		70E				
Black-fronted Dotterel	*Elseyornis melanops*			1				
Masked Lapwing	*Vanellus miles*	4						
Latham's Snipe	*Gallinago hardwickii*	4		1				
Yellow-tailed Black-Cockatoo	*Calyptorhynchus funereus*		4				6	2
Gang-gang Cockatoo	*Callocephalon fimbriatum*						6	3
Sulphur-crested Cockatoo	*Cacatua galerita*							1
Crimson Rosella	*Platycercus elegans*		7	2	4		5	6
Eastern Rosella	*Platycercus eximius*		1	2				
Pallid Cuckoo	*Cacomantis pallidus*			1				
Fan-tailed Cuckoo	*Cacomantis flabelliformis*			1			1	
Powerful Owl	*Ninox strenua*, **T**						1	
Southern Boobook	*Ninox novaeseelandiae*		1					1
Laughing Kookaburra	*Dacelo novaeguineae*		2		1		3	1
Superb Lyrebird	*Menura novaehollandiae*							1
White-throated Treecreeper	*Cormobates leucophaea*		3				5	3
Superb Fairy-wren	*Malurus cyaneus*	8	2		10	3	4	10
White-browed Scrubwren	*Sericornis frontalis*	6	2		2	2	4	3
Striated Thornbill	*Acanthiza lineata*		2				2	
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*							10
Brown Thornbill	*Acanthiza pusilla*		5		2	2	4	1
Spotted Pardalote	*Pardalotus punctatus*	1	1					1
Striated Pardalote	*Pardalotus striatus*			1				
Eastern Spinebill	*Acanthorhynchus tenuirostris*						1	
Yellow-faced Honeyeater	*Lichenostomus chrysops*		5					

Table. 5. cont'd.

		Survey sites						
Species		**1**	**2**	**3**	**4**	**5**	**6**	**7**
White-eared Honeyeater	*Lichenostomus leucotis*	10	5		5		1	1
Red Wattlebird	*Anthochaera carunculata*						3	2
White-fronted Chat	*Epthianura albifrons*			1				
Crescent Honeyeater	*Phylidonyris pyrrhopterus*						1	3
New Holland Honeyeater	*Phylidonyris novaehollandiae*	1					2	1
White-naped Honeyeater	*Melithreptus lunatus*		1		1		3	2
Eastern Whipbird	*Psophodes olivaceus*		1	1	2		2	2
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	2	2	1	2		3	
Crested Shrike-tit	*Falcunculus frontatus*						1	6
Golden Whistler	*Pachycephala pectoralis*				5		1	2
Rufous Whistler	*Pachycephala rufiventris*		6	10		5		
Grey Shrike-thrush	*Colluricincla harmonica*	2	2	1	2		2	1
Olive-backed Oriole	*Oriolus sagittatus*			1				
Grey Butcherbird	*Cracticus torquatus*		2		5		1	
Australian Magpie	*Cracticus tibicen*	10	5		5		2	2
Pied Currawong	*Strepera graculina*		1		1			
Rufous Fantail	*Rhipidura rufifrons*		1					
Grey Fantail	*Rhipidura albiscapa*	3	11		6	1	5	1
Willie Wagtail	*Rhipidura leucophrys*	2		1	1			
Australian Raven	*Corvus tasmanicus*	1					1	
Magpie-lark	*Grallina cyanoleuca*	2		1	1			1
Scarlet Robin	*Petroica boodang*						1	
Flame Robin	*Petroica phoenicea*							10
Eastern Yellow Robin	*Eopsaltria australis*		4	1	4	1	6	2
Golden-headed Cisticola	*Cisticola exilis*	5		1		2		
Australian Reed-Warbler	*Acrocephalus australis*			15E		10E		
Silvereye	*Zosterops lateralis*	2	4		3			
Welcome Swallow	*Hirundo neoxena*			20E	2		6	
Tree Martin	*Petrochelidon nigricans*	6		10				
Bassian Thrush	*Zoothera lunulata*		1				2	
Common Blackbird	*Turdus merula* *		1	1		2	3	10E
Common Starling	*Sturnus vulgaris* *	2		20E	1			20E
Common Myna	*Sturnus tristis* *			5				
Red-browed Finch	*Neochmia temporalis*	6					4	
Australasian Pipit	*Anthus novaeseelandiae*					1		
European Goldfinch	*Carduelis carduelis* *	10				3		

chenostomus leucotis, White-browed Scrubwren *Sericornis frontalis*, Superb Fairy-wren *Malurus cyaneus*, Olive-backed Oriole *Oriolus sagittatus*, Rufous Whistler *Pachycephala rufiventris*, Grey Shrike-thrush *Colluricincla harmonica* and Golden-headed Cisticola *Cisticola exilis*. Numerous species were detected only in remnant patches, including Rufous Fantail *Rhipidura rufifrons*, Bassian Thrush *Zoothera lunulata*, Eastern Whipbird *Psophodes olivaceus*, Striated Thornbill *Acanthiza lineata*, White-throated Treecreeper *Cormobates leucophaea*, Golden Whistler *Pachycephala pectoralis* and Yellow-faced Honeyeater *Lichenostomus chrysops* (see page 134). The Crested Shrike-tit *Falcunculus frontatus*, a species in decline nationally (Barrett *et al.* 2003), was found in only three remnant patches. A flock of Flame Robins *Petroica phoenicea* was observed on the edge of Grassy Dry Forest in May 2008. This species disperses in autumn and winter to lower altitudes and is commonly seen in open, fragmented landscapes (Pizzey and Knight 2007). The Superb Lyrebird was recorded in site 7, where two active display mounds and fresh rakings typical of those made by the species were found. The size of territory for Superb Lyrebird can be as small as 0.9 hectares (Reilly 1988) and the species has

been found in other small, isolated remnants (A Lill, Monash University pers comm.; J Machunter, Arthur Rylah Institute, pers comm.). During a visit to site 6 on 25 October 2007, Mr Rob Moss (IDLM) photographed a large owl roosting in thick vegetation. The photograph was examined by Dr Rolf Willig, Senior Biodiversity Officer, West Gippsland, DSE, Traralgon and identified as a Powerful Owl *Ninox strenua*. The species is classified as vulnerable in Victoria (DSE 2007). Common and scientific names and taxonomy for birds follow Christidis and Boles (2008).

Discussion

The Agile Antechinus is possibly the most widespread and abundant small marsupial in south-eastern Australia. The species is found in a wide range of vegetation communities including those in damp gullies, wet and dry forests and woodlands, but highest densities usually occur in wetter environments (Menkhorst 1995). Prior to 1998, the species was known in Victoria and south-east New South Wales as the Brown Antechinus *Antechinus stuartii* (Dickman *et al.* 1998). The Agile Antechinus has small home ranges (Lazenby-Cohen and Cockburn 1991) and both sexes share communal nests before and into the mating season (Lazenby-Cohen 1991). During studies in south-east New South Wales between 1983 and 1990, up to 24 males and 28 females were found to share nests (Cockburn and Lazenby-Cohen 1992). Also during these studies a strong preference was shown for large trees for nest sites. Capture rates for the Agile Antechinus can vary significantly depending on habitat structure and the time of year when trapping surveys are conducted. All males die following a two week mating period in August (Menkhorst and Knight 2004) and therefore surveys in the La Trobe Valley were planned for autumn to obtain maximum results. Sites that were assessed as having potential Antechinus habitat were targeted.

During the surveys of offset areas within the YMCMP, capture rates for the Agile Antechinus were 5.3% at site 7, 12% at site 2 and a very high 37.3% at site 6. Site 6 contained many large fallen, hollow logs and many mature eucalypts with large hollows. The species was recorded in Damp Forest and Lowland Forest at this site. Site 2 also contained numerous suitable habitat trees as well as smaller numbers of fallen logs. Agile Antechinus was recorded on the dry slopes of this area as well as in the damp gully. Site 7, however, where the lowest capture rate was achieved, had far fewer fallen logs and few suitable habitat trees. The Agile Antechinus has been recorded previously in remnant, isolated habitat patches in southern New South Wales (Banks *et al.* 2005a; Banks *et al.* 2005b; Lindenmayer *et al.* 1999), in north-eastern Victoria (Suckling and Heislers 1978), in western Victoria (Bennett 1990; Wallis *et al.* 2007) and near Koonwarra in South Gippsland in 1998 and 1999 (Homan unpubl. data; FNCV unpubl. data). Banks *et al.* (2005a and 2005b) investigated the impacts of habitat fragmentation due to the establishment of softwood plantations on various aspects of the ecology of the Agile Antechinus. During these studies Agile Antechinus was recorded in remnant patches, surrounded by softwood plantations, ranging in size from 0.6 to 31.1 hectares. Patch occupancy was influenced mainly by quality of habitat and geographic isolation. Very small patches where Agile Antechinus were recorded were within 50-170 metres of the nearest area of suitable habitat also occupied by the species. Lindenmayer *et al.* (1999) suggested that the Agile Antechinus can move through softwood plantations and colonise remnant, isolated areas. The three sites within the YMCMP where Agile Antechinus were recorded have all been isolated for at least 40 years and each is many kilometres from the nearest area with habitat suitable for the species. Furthermore, each site is surrounded by greatly altered landscapes that would make movement impossible for any small terrestrial mammal. Clearly, each remnant patch contains suitable habitat of varying quality and is large enough to support populations of Agile Antechinus. Despite this, populations in each area are under threat from wildfire, a natural occurrence that is predicted to increase with climate change.

The Dusky Antechinus is widespread, but not as abundant as the Agile Antechinus. The species inhabits damp areas and shows a preference for dense vegetation up to one metre above ground level. The Dusky Antechinus is almost entirely terrestrial and nests in burrows or in logs or stumps (Menkhorst 1995). However, the Dusky Antechinus is not seen as a species that would be expected to survive in small remnant patches (P Menkhorst pers. comm). The species has been recorded in dis-

Fig. 2. Swamp Skink *Egernia coventryi*. Photo by Rob Moss.

turbed habitats during surveys in pine plantations in north-east Victoria (Suckling and Heislers 1978), but was largely confined to dense native vegetation along creeks. More recently, the species was recorded in a ten hectare isolated patch of Damp Forest near Kinglake in central Victoria in October 2008 (Northern Melbourne Institute of TAFE unpubl. data). The Dusky Antechinus was recorded only at site 7, where large areas of dense ground cover of Fishbone Water Fern and Thatch Saw-sedge occur in three relatively isolated gullies. This vegetation structure, however, does not occur in large areas at site 6, where the one gully has a very dense understorey in many parts, causing heavy shade, thus producing a much more open ground cover. Also at site 6, a four-wheel-drive track runs beside the gully for its entire length. The relatively wide shape of site 7, the vegetation structure and topography may help to explain why the species has persisted in this area for at least the last 40 years.

The Bush Rat is widespread and common in many parts of Victoria. The species favours moderate to dense ground cover and requires friable soil in which to construct burrows (Menkhorst 1995). Bush Rats were recorded in several sites including small remnants, wet gullies, riparian areas and one revegetation site. A feature of each site was the presence of moderate to thick ground cover and usually fallen logs. At site 2 the species was recorded only in the wet gully, an area covering approximately four ha. The highest capture rate of 27.5% was achieved at site 3 in a damp riparian area with very thick ground cover of Variable Sword-sedge. Other studies have shown that the Bush Rat favours riparian areas with dense, low vegetation (Laidlaw and Wilson 1989; Suckling and Heislers 1978). At the Morwell River Wetlands one Bush Rat was captured in a revegetation area where logs and rocks had been provided amongst a thick cover of Common Tussock Grass and Spiny Mat-rush. This capture took place three years after the site had been planted and was about 200 m from a known population of Bush Rat. Also at the Morwell River Wetlands, a population of Bush Rats was found

in a small remnant of Swamp Scrub covering approximately three ha. Prior to construction of the wetlands, this area was an island of native vegetation surrounded by grazing land and roads. It had been isolated for at least 40 years. Bush Rats are territorial (Menkhorst 1995); however, studies carried out on populations on off-shore islands have shown that animals may show more tolerance of strangers than those in mainland populations (Breed and Ford 2007). Bush Rats have small home ranges of less than half a hectare (Breed and Ford 2007) and those isolated in small remnant habitat patches may display similar habits to those on off-shore islands to ensure survival.

The Swamp Rat is widely distributed throughout southern Victoria. It is found in sedgefields and wet heath, but also inhabits grassy roadsides and riparian areas (Menkhorst 1995). The Swamp Rat was detected in a number of sites, especially around the edges of artificial wetlands and in disturbed sites. At the Morwell River Wetlands the species had colonised revegetation areas around the edges of wetlands as well as on islands, within three years of plantings. At site 3 Swamp Rats were not recorded in the riparian area of Variable Sword-sedge where high numbers of Bush Rat were found. Swamp Rats were, however, found in an adjacent area of degraded Swamp Scrub at this site. Other studies have found that away from sedgy swamps the Bush Rat excludes the Swamp Rat (Breed and Ford 2007). At site 3 many burrows and runways typical of those made by Swamp Rats were present around the oldest wetland. At the time of the survey of this site Swamp Rats had not colonised the edges of the more recently constructed wetlands. During preliminary visits to a number of sites prior to stock exclusion, Swamp Rat runways and burrows were found only in areas that did not suit stock or where stock could not reach. Swamp Rats are very susceptible to disturbance, especially from trampling by stock (Menkhorst 1995). However, since fencing has been completed and stock removed, Swamp Rat runways and burrows have appeared over extensive areas of previously grazed grasslands at several sites. Similar results have been achieved at other sites in Victoria. At Inverloch in South Gippsland, Swamp Rats had colonised former public camping areas that had been fenced and allowed to regenerate (Homan 2002). On a grazing property near Buangor in western Victoria, Swamp Rats had colonised all areas of fenced-off, previously grazed grassland (Homan 2004).

The Sugar Glider is common and widespread throughout much of Victoria. It inhabits a wide range of forest types and woodlands, but requires hollows in trees for nesting sites and usually an understorey of *Acacia* spp. as a winter food source (Menkhorst 1995). The Sugar Glider was recorded in degraded riparian vegetation along the Morwell River at sites 1, 4 and 5, where several old-growth Strzelecki Gums survive with an understorey of Silver Wattle. Populations of Sugar Gliders have been found in other fragmented remnants during intensive studies on the Gippsland Plain (Suckling 1984). The species has also been recorded in other parts of Victoria in fragmented landscapes in the Strathbogie Ranges (Downes *et al.* 1997), at Edgecombe (Lunt 1988), at Kyneton and Stawell (Homan unpubl. data) and South Morang (Homan 2006b).

The Mountain Brushtail Possum, also known as the Bobuck, is common in wet forest in much of eastern Victoria (Menkhorst 1995) and is also found as far west as Mount Cole in western Victoria (Thompson 1993). The Mountain Brushtail Possum was separated taxonomically from the Short-eared Brushtail Possum *Trichosurus caninus* in 2002 (Van Dyck and Strahan 2008). The species dens in tree hollows, hut also uses hollows in fallen logs (Owen and Thomson 1965). Extensive studies into the habitat requirements and use of nest trees by the species have been carried out in the Central Highlands of Victoria (Lindenmayer *et al.* 1990; Lindenmayer *et al.* 1991; Lindenmayer *et al.* 1996a, 1996b, 1997; Welsh *et al.* 1998). These studies indicate that the Mountain Brushtail Possum prefers forests in gullies with large numbers of hollow-bearing trees with an understorey including *Acacia* spp. The studies also found that the species prefers trees with numerous hollows. Radio-tracking showed that the Mountain Brushtail Possum moved frequently between nest sites, with some individuals using up to six different sites per week (Lindenmayer *et al.* 1996a). Owen and Thomson (1965) repeatedly observed the movement of eight Mountain Brushtail Possums and found that the home range of these individuals was especially linear. The Mountain Brushtail Possum was recorded only in site 6, which contains a relatively narrow gully

stretching for a considerable distance through Damp Forest. Three individuals were seen by spotlighting, one on the ground and the other two about two m from ground level. Two were also caught in cage traps set on the ground, one in the gully and one near a ridge in Lowland Forest. Owen and Thomson (1965) found that the Mountain Brushtail Possum spends considerable time feeding on the ground. Site 6 also contains many large, hollow logs and numerous mature eucalypts with large hollows, with an understorey that includes Silver Wattle. The shape of this site, vegetation structure and topography clearly suits the habitat requirements of the Mountain Brushtail Possum.

The Swamp Skink inhabits low-lying swampy areas, sedge-tussock vegetation and salt marshes. The species is secretive and shelters in burrows including those of crustaceans (Cogger 2000; Wilson and Swan 2003). However, destruction of its preferred habitat has led to a disjunct distribution and the species is listed as vulnerable in Victoria (DSE 2007). One Swamp Skink was recorded beside a degraded wetland at site 5. The specimen was captured in a funnel trap set in an open site between weeds and a revegetation area. Many large burrows of crustaceans were a feature of this site. Swamp Skinks can be observed basking in reeds and on horizontal and fallen branches and trunks of paperbarks (Clemann 2000; Homan 2006a). However, despite careful and prolonged scanning of potential basking sites with binoculars, none was detected using this survey method. Most records for the Swamp Skink are from coastal areas, but a number of other records exist from inland localities including Enfield (Clemann and Beardsell 1999) and the Grampians in October 2008 (RMIT University unpubl. data). Another probable record for the Swamp Skink exists from near Traralgon from 1997 (N. Clemann unpubl. data). Other records from degraded and weedy habitat (Clemann 2000; Homan 2006a) also exist for this species in Victoria. Clemann (2000) suggests that caution should be exercised when assuming that the Swamp Skink may not be present in marginal habitat.

The Glossy Grass Skink is found in similar habitat to the Swamp Skink (Wilson and Swan 2003). One Glossy Grass Skink was found under discarded galvanised iron in a heavily grazed paddock, adjacent to site 5 where the Swamp Skink was recorded. One other record for the species exists from the Gippsland Plain near Churchill, approximately 10 km south of this site (Atlas of Victorian Wildlife). It is not unusual to find the Swamp Skink and the Glossy Grass Skink at the same site (N Clemann pers. comm). During a reptile survey at Wonthaggi in 2001, several individuals of both species were captured in the same pitfall line established amongst sedgy vegetation (Homan 2003).

Several common and widespread amphibian species are known to occur in disturbed sites and to colonise artificial wetlands (Hero *et al.* 1991; Robinson 1993). Studies at Eltham and Glen Iris in Victoria (Ralston and Moir 1998; Homan 1999) showed that recently constructed wetlands were colonised by several species including Southern Brown Tree Frog, Spotted Marsh Frog, Striped Marsh Frog, Common Froglet and Southern Bullfrog. During a study in revegetation areas in western Victoria, Southern Brown Tree Frog was often found in narrow riparian revegetation strips (Merritt and Wallis 2004).

Several studies have been conducted into the use of artificial wetlands by amphibians (Hazell *et al.* 2001; Hazell *et al.* 2004; Alsfeld *et al.* 2009). Hazell *et al.* (2004) compared natural ponds to constructed farm dams at 44 sites in an agricultural landscape in southern New South Wales. The study concluded that artificial wetlands have a conservation role in providing habitat for frogs and supported similar numbers of species to natural wetlands. Hazell *et al.* (2001) examined the use by frogs of 70 farm dams and five semi-natural wetlands in the upper Shoalhaven catchment in New South Wales. Results showed a positive relationship between the presence of emergent vegetation and the presence of cover in the surrounding terrestrial environment. Alsfeld *et al.* (2009) suggested that coarse woody debris should be added to constructed wetlands to enhance biodiversity and especially to provide habitat for aquatic insects, which form a major food source for aquatic vertebrates. Major features of the artificial wetlands at sites 1 and 3 included the presence of emergent vegetation and woody debris, in the form of old stumps and logs, in the water bodies and around the edges. At site 3, one Verreaux's Tree Frog was found under a section of log that had been placed on the edge of the wet-

land. Whilst numerous species were recorded in artificial wetlands, Victorian Smooth Froglet was recorded only in undisturbed areas in sites 4, 6 and 7. The Southern Toadlet *Pseudophryne semimarmorata*, a species whose range includes the La Trobe Valley, was not recorded during these surveys. Records for the species have declined in recent years and it is now classified as vulnerable in Victoria (DSE 2007). Males call from depressions or burrows during autumn, and several areas within the survey sites had the potential to provide records of this species. However, despite several rain events occurring during visits to these sites, no calls of this species were heard.

The greatest diversity of forest birds was found in the largest remnant patches with the highest quality vegetation. This was especially so at sites 2, 6 and 7 and in the Riparian Forest section of site 4. Several species were detected in low numbers and were confined to wet gullies or dense vegetation. The Rufous Fantail was detected in the gully at site 2, the Bassian Thrush was seen at this site and also in the gully at site 6, whilst the Eastern Whipbird was heard in several sites with dense vegetation. Fewer species were recorded in revegetation areas. Wallis *et al.* (2007) found similar trends during a study in remnant patches and revegetation areas in western Victoria during the spring and summer of 2001/2002. Loyn (1985) conducted surveys in 56 remnant forest patches on the Gippsland Plain between 1980 and 1983. During those surveys the largest patches with the highest quality habitat were found to support the greatest number of species of forest birds. Bassian Thrush, Rufous Fantail and Eastern Whipbird were detected in low numbers, the latter two being confined to gullies.

The presence of the Powerful Owl and the White-bellied Sea-Eagle in this largely agricultural and industrial district is noteworthy and shows the importance of remnant areas to threatened species (R Willig pers. comm.). The fact that the White-bellied Sea-Eagle has been recorded as breeding in such a highly modified environment is especially noteworthy. The species is often recorded near large inland water bodies (Debus 2001) and is regularly seen over the Yallourn Wetlands (R Willig pers. comm.).The sighting of a Powerful Owl at site 6 was, in many ways, not unexpected. The size of this site and habitat is ideal for the species, with many large hollows and an ample supply of Common Ringtail Possum, a favourite prey species for the Powerful Owl (Menkhorst 1995). Loyn (1985) also detected Powerful Owl in two of the largest patches during his study on the Gippsland Plain.

The recording of a wide range of vertebrate species during these surveys in a highly fragmented and disturbed landscape is particularly noteworthy. Further surveys of these sites at different times of the year may reveal even more species, especially amphibians and bats, but also many more breeding records of birds. Land managers assessing the value of areas for conservation should be aware that a variety of species may be present in small remnants or even the most degraded sites. This is especially so for cryptic species that may be difficult to detect and may be recorded only by using a range of intrusive and non-intrusive survey techniques. An excellent example of this was the capture of the Swamp Skink, along with several other reptile species, beside degraded Reed Swamp at site 5. Land owners and managers should thoroughly investigate the potential of sites before rejecting areas as not being worthy of preservation or worthy of revegetation or habitat enhancement programs.

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The Grey Squirrel *Sciurus carolinensis* in Adelaide, South Australia: its introduction and eradication

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Abstract
In addition to its known former presence in Melbourne and Ballarat, in Victoria, the presence of the Grey Squirrel *Sciurus carolinensis* in Adelaide, South Australia from 1917 to about 1922 is detailed. Founder animals were likely sourced from the Melbourne population, with the Adelaide Grey Squirrel population subsequently arising from escapes from the zoological gardens, or animals privately sourced from Toorak, Victoria. Relatively prompt action by Government to control the Squirrels saw a bounty offered and the apparent main population controlled by Adelaide City Council staff. The Squirrels, restricted to urban plantings of northern hemisphere trees, were subsequently eradicated and were last recorded in 1922. It is unknown what contribution either control method contributed to the eventual eradication of this introduced species. The successful eradication of the Grey Squirrel from Adelaide provides an additional international vertebrate pest eradication record to further our understanding of achieving success in this difficult but valuable pest management goal.
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Keywords: Grey Squirrel, trapping, urban, bounty, pest control

Introduction

The Grey Squirrel *Sciurus carolinensis* Gmelin is a native of the eastern half of North America (Koprowski 1994). Seeds, fruits and flowers of northern hemisphere plants dominate its diet, but it is also recorded consuming fungi, insects and bird eggs and nestlings (Seebeck 1989; Koprowski 1994). Though a species that cannot hibernate (Seebeck 1989), the Grey Squirrel still requires den sites, the formation of which can take up to 30 years in their preferred northern hemisphere plants (Koprowski 1994). Densities can reach >21/ha in urban areas (Koprowski 1994).

In his comprehensive compilation of mammal introduction accounts, Long (2003) detailed the early twentieth century introduction of the Grey Squirrel to Melbourne (Barrett 1934; Watts and Aslin 1981; Seebeck 1984) and subsequently to Ballarat, Victoria (Watts and Aslin 1981). That this species was also introduced into, and subsequently eradicated from, Adelaide, South Australia, also in the early twentieth century, appears to have escaped notice (Clayton *et al.* 2006, plus amendments).

First reference to the Grey Squirrel in Adelaide appears to be an August 1919 media article highlighting their depredations of walnuts, acorns and pine seeds in the Botanic Garden (depredation also reported in Brooker and Bailey 1919) and presenting their potential to 'become a serious scourge unless action is immediately taken to combat it effectively' (Anon 1919a p. 9). Reference to then current primary producer losses from the introduced Red Fox *Vulpes vulpes* and European Rabbit *Oryctolagus cuniculus* may have aided general awareness and sensitivity towards the potential threat of another introduced pest, and stimulated rapid management of the problem. However, the response to this introduced pest, described by Seebeck (1984 p. 66) as 'probably the most attractive – and certainly one of the most inoffensive [introduced animals]', seems somewhat incongruous, although ultimately seemingly effective, arising apparently from one newspaper article. Whether or not there was any associated public and industry pressure for management of this animal is unknown, but it appears to have been limited, with no evidence in associated media articles.

A meeting to discuss the Grey Squirrel issue was requested by State Government and held with the Directors of the Botanic and Zoological Gardens, probably in late October 1919. The outcome of this meeting is detailed in a report highlighted in November 1919 in the second and apparently last major media article on the issue (Anon 1919b p. 5). Mention in the report of the squirrels affording 'a further illustration of the absolute necessity for the department having power to prohibit any person from bringing into the State, without permission, any bird or animal' suggests the Government's response to the squirrels may have arisen in part from a desire for additional import control powers.

Methods

In seeking to substantiate and document the former distribution, abundance and eradication of the Grey Squirrel in Adelaide, newspapers of the period via The Manning Index of South Australian History (http://www.slsa.sa.gov.au/manning/search.html), state records, Adelaide City archival files and archival material in the Burnside Council library were searched.

The report published in the media (Anon 1919b), an Adelaide City file of correspondence on the issue (TCDKT1919/3418), a review of '*South Australia. Botanic Garden – Report for the year 1917-18*' to the year ended 30 June 1922, and a review of '*South Australia. Report of the Board of Governors of the Botanic Garden of Adelaide*' for the years 1922-23 to 1924-25, provided primary information on the distribution, relative abundance and management of the Grey Squirrel in Adelaide. No documentation could be located in likely State Record files or the Burnside Council library (archives).

Origin of Grey Squirrels

Although a letter published in response to these media articles suggests some squirrels may have been present in Adelaide ~30 years earlier [~1890] (Horsnell 1919), soon after their reported introduction to Melbourne (Barrett 1934; Seebeck 1984) and interestingly less than five kilometres from their reported 1917 release site, it appears they either did not persist, or perhaps were misidentified possums – a suggestion I received for some of my enquiries!

There appear to be two hypotheses for the origin of the Grey Squirrels that established in Adelaide in 1917. The first was suggested by the media, being that the squirrels arose from Zoological Garden escapees (Anon 1919a). The second was proposed in the report to Government, being that they appear to have arisen from 'a resident from the eastern suburbs' introducing some squirrels 'two years ago [1917]' from the introduced population at Toorak, Victoria (Anon 1919b p. 5). Both hypotheses appear to have support, with both pathways enabling other successful international introductions (Bertolino 2009). The likelihood that this species would establish from as few as a single pair was 0.57 per cent (Bertolino 2009).

The Botanic Garden and Park, which lie adjacent to the zoo, have received most mention and appear to have been the centre of the squirrel population. This is consistent with the hypothesis of zoo escape and parallels the situation in Victoria, with both populations centred on their release sites. However, the South Australian Museum has three specimens of *S. carolinensis*, with two of them (M01486 and M01487) being mounted skins from squirrels sourced in 1922 from the Adelaide Zoo. [The other (M18615) is a skull sourced from S. McEwen in 1996 from an unknown location]. Adelaide Zoo has no record of their previous Grey Squirrel collection and hence the two squirrels provided to the

museum might have been their entire captive colony, or perhaps were wild Squirrels sourced from their precinct (L. Andrews Adelaide Zoo 2008 pers. comm. 12 August). If they were the zoo's collection of Grey Squirrels, their demise in 1922 and provision to the museum may have been coincidental with the demise of the wild population, or a conscious decision to remove this source of potential escapees and zoo criticism (as per Anon 1919a).

Support for an eastern suburbs resident releasing the squirrels is found in the detail provided for this hypothesis, including source of the animals, their origin, cage design and escape (Anon 1919b). Criticisms could be that one of its supporters, presenting it to contradict the zoo escape hypothesis, was the then zoo director, and that little documentation could be found for the existence and eradication of squirrels in this area cf. the numerous reports for the Botanic Garden and Park, and those for Victoria, which relate to their original release sites.

Distribution and abundance

It appears that the squirrels were limited in distribution to an area of approximately 40 km^2 north and east of the city centre. Reported locations (Fig. 1) and abundance include:

- 'the pest has multiplied rapidly ... and appears to be distributed over a considerable portion of the metropolitan area. There are hundreds and possibly thousands of them in the Botanic Park and garden, and they have also been observed as far afield as Glen Osmond and Montefiore Hill' (Anon 1919a p. 9).
- 'more or less numerous in the timbered areas from Burnside to Walkerville, but we have no exact knowledge of the extent of their spread.' Not unusual in an evening to see 'half a dozen at different places' in the Botanic Garden (Anon 1919b p. 5).
- 'more or less numerous in the various plantations through the Parks, along the River [Torrens] and out toward Burnside' (letter from the secretary of the Office of the Minister of Industry dated 5 November 1919, in TCDKT1919/3418).
- 'in the Plantations along the War-Memorial-Drive & in Montefiore-Hill-Plantations; they are not numerous' (letter from 'City Gardener' dated 8 November 1919, in TCD-KT1919/3418).

Control

An outcome of the meeting to discuss the squirrel issue was 'that immediate action is necessary on the part of the Government ... and that the only effective way would be to offer a bonus for all skins' (Anon 1919b p. 5). This approach was put to the Adelaide City Council with a request that they 'share half the cost in so far as any Squirrels taken within the City Boundaries are concerned' (letters from the Secretary of the Office of the Minister of Industry dated 5 November and 8 December 1919, in TCD-KT1919/3418). Council declined the request for financial assistance but agreed to undertake 'other measures' to destroy the squirrels in their Council area, eventually instructing their foreman to use a shotgun to shoot squirrels 'in the parklands in the vicinity of the Nursery ... only shot when in the trees' (letters from the Town Clerk to the Office of the Minister of Industry dated 22 December 1919 and to the City Gardener dated 13 January 1920, in TCD-KT1919/3418).

No records of the 2/6d. (2 shillings and sixpence; = AU$7.11 @ 2008 – www.rba.gov.au/calculator/calc.go) bounty payments by Government could be located, but it is likely that they were paid out for squirrel skins over their whole distribution, from January 1920 (Fig. 2) to perhaps 1922, the year they were last reported in the Botanic Garden (Brooker and Bailey 1922, 1923). The only record of squirrels being trapped for the bounty is the account described in Pitt (1967 p. 7) and this was from the Adelaide City Council area. In this account the then Museum taxidermist had two squirrels released that he had trapped outside 'the Archives' for the bounty. The lady who released the squirrels commenced her position in 1921, so this account may have come from this year or perhaps 1922 (Brooker and Bailey 1922, 1923).

Discussion

The story of the Grey Squirrel in Australia now involves three introductions, Melbourne, Ballarat and Adelaide. All of these populations have now disappeared. In our desire to understand success and failure in vertebrate introductions (Bertolino 2009; Simberloff 2009), it appears the critical issues of suitable habitat, predation, competition and control effort have all influenced the failure of these introductions.

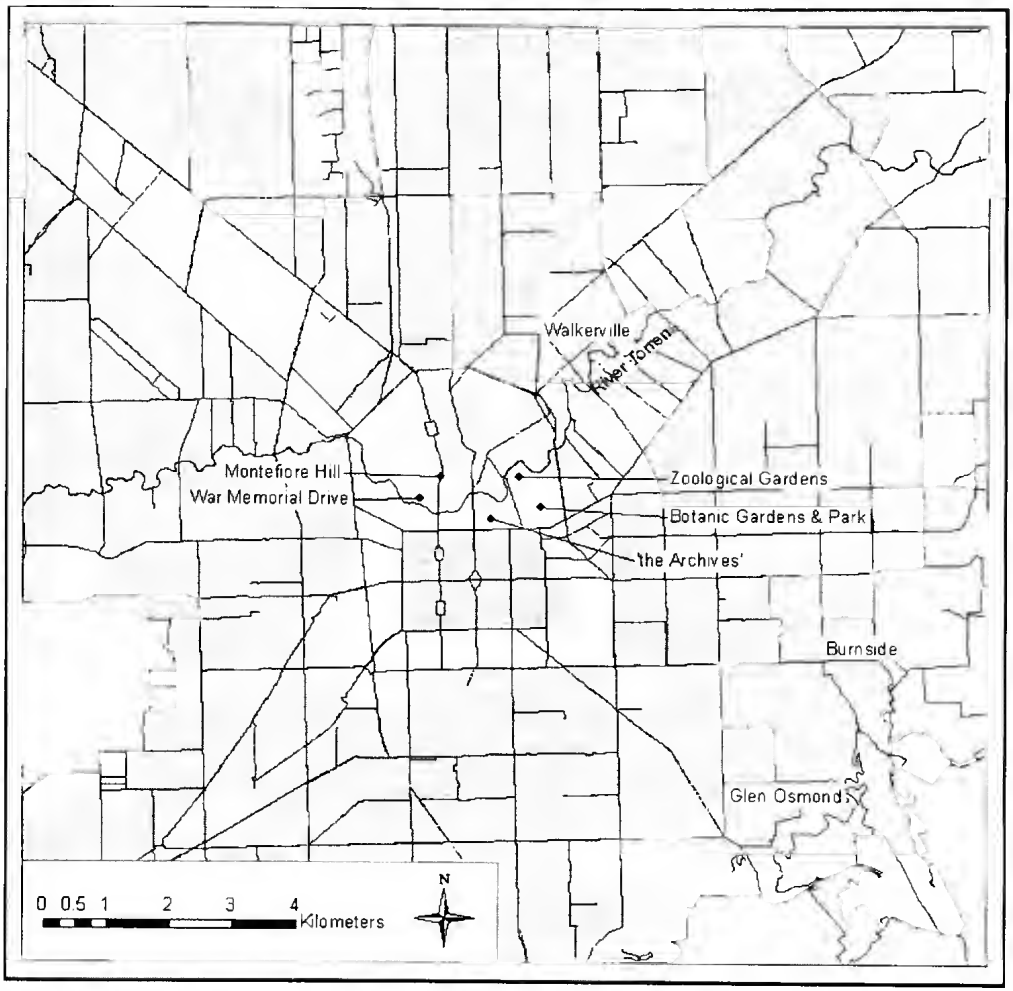
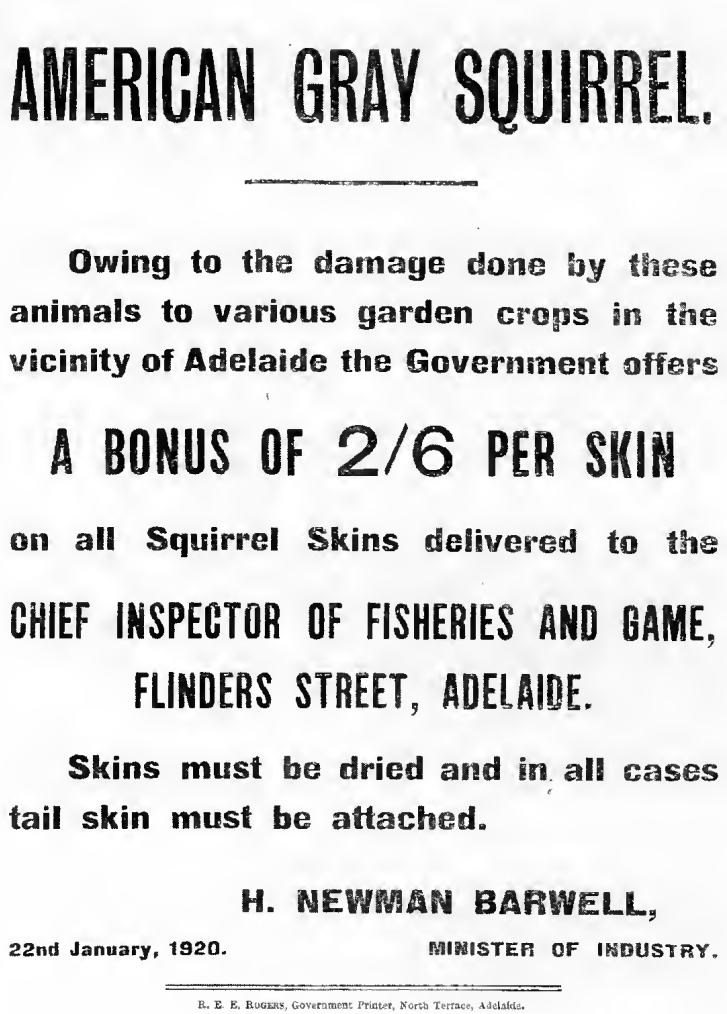


Fig. 1. Distribution of the Grey Squirrel in Adelaide, South Australia relative to the city centre (in the middle), showing place names as used in the text.

All introductions were spatially restricted (~4-60 km^2; Seebeck 1984) and limited to botanical gardens and urban areas where plantings of northern hemisphere trees such as oaks and pines, and the supplemental feeding by people, could support these exotic animals. However it appears that this limited seasonal and sporadic food supply, coupled with competition from Brush-tailed Possums *Trichosurus vulpecula* and some Cat *Felis catus* predation, were critical factors in the demise of the two Victorian Grey Squirrel populations (Seebeck 1984). Their survival for perhaps 60 and 36 years in Melbourne and Ballarat respectively, compared with only about five years in Adelaide, appears primarily related to active control being undertaken only on the Adelaide population.

An interesting comparison is found in the Five-lined Palm Squirrel *Funambulus pennanti* introduced to the South Perth Zoological Gardens in 1898 (Sedgwick 1968) and to Sydney's Taronga Park Zoo, likely at about the same time (Watts and Aslin 1981). Like the South Australian and two Victorian (Seebeck 1984) Grey Squirrel populations, both Palm Squirrel populations remained strongly associated with their release sites. For the Sydney population this was until their demise in about 1977,



AMERICAN GRAY SQUIRREL.

Owing to the damage done by these animals to various garden crops in the vicinity of Adelaide the Government offers

A BONUS OF 2/6 PER SKIN

on all Squirrel Skins delivered to the

CHIEF INSPECTOR OF FISHERIES AND GAME, FLINDERS STREET, ADELAIDE.

Skins must be dried and in all cases tail skin must be attached.

H. NEWMAN BARWELL,

22nd January, 1920. **MINISTER OF INDUSTRY.**

R. E. E. ROGERS, Government Printer, North Terrace, Adelaide.

Fig. 2: 1920 bounty poster for the Grey Squirrel in Adelaide, South Australia (originals on file in TCD-KT1919/3418).

speculated due to loss of habitat trees and rat bait poisoning (Watts and Aslin 1981). This demise with non-targeted control measures somewhat parallels the active control measures causing loss of the South Australian Grey Squirrel population. In comparison, the Perth Palm Squirrel population remains extant and an active management issue. Though still concentrated at its zoo release site, human movement of the animals has resulted in new city and regional outbreaks being identified (JL Long and WA Department of Agriculture and Food; unpubl. data).

The decision to commence control of Grey Squirrels within two years of their release (Anon 1919b) obviously limited the distribution and abundance of Grey Squirrels in Adelaide, minimised control costs and maximised the likelihood of eradication (Simberloff 2009). Because no records of bounty payments were located, it cannot be established what contribution this strategy had on the control of this pest. How-

ever, the decision of the Adelaide City Council to undertake shooting of the squirrels in their area, seemingly the species' population centre, was probably a critical factor. An alternative decision to tolerate the squirrels' impacts on garden, orchard and plantation plants, due to a belief that they were of greater aesthetic value, coupled with urban support and supplemental feeding, could have enabled persistence of this vertebrate pest in the Adelaide urban environment.

Acknowledgements

The account from Pitt (1967) was located and generously forwarded by Terry Sim and provided the foundational knowledge of the historical presence of squirrels in Adelaide. The accounts of Anon (1919a, b) were located by Geoffrey Manning and sourced via The Manning Index of South Australian History (http://www.slsa.sa.gov.au/manning/search.html). David Stemmer, South Australia Museum, is thanked for confirming the details of Grey Squirrel specimens in the collection of this institution. Lindell Andrews, Animal Records Officer at Adelaide Zoo; Lorrae West, Botanic Gardens and State Herbarium Library; and Andrew Ward, Burnside Council Library, are thanked for checking their records for any correspondence relating to the Grey Squirrels. Marion Massam (WA Department of Agriculture and Food) is thanked for providing unpublished data on the Palm Squirrel. Ian Abbott (WA Department of Environment and Conservation) is thanked for providing comment on the manuscript.

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One Hundred and One Years Ago

FROGS. — Among my exhibits at the recent conversazione were two frogs (Crinia?) which lay their eggs away from water; also a number of tadpoles hatched from eggs laid away from water. Some of the eggs were merely kept moist, and the tadpoles emerged in about forty-eight hours, but from a number of the eggs which were dropped into an aquarium on 1st June last the tadpoles did not emerge till 29th July and later. Why should there be so great a difference between the hatching in air and in water?—H. W. WILSON.

From *The Victorian Naturalist* **XXV**, p. 120, November 5, 1908